Space Weather Technical Forecast

Issued on Wednesday, 22 December 2021 at 01:21 Local

This technical forecast provides a four day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

Space Weather Forecast Headline: Chance of G1/Minor Storm on Day 2 (23rd). Occasional M-class flares likely throughout. Chance of Active electron fluence developing later in the period.

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Solar activity has been Moderate over the past 24 hours, with numerous C-class X-ray flares observed, and two M-class flares at 21/0750 UTC and 21/1144 UTC originating from the newly AR2916 rotating around from the east limb. A previous M class flare at 20/1136UTC, from an active region in the southern hemisphere near the centre disc, produced a weak coronal mass ejection (CME). Analysis of this CME indicates an arrival time on day 3 (23 Dec).

There are currently ten numbered sunspot regions on the visible disc, which includes two newly numbered regions AR2915 and AR2916 both in the southeast quadrant. These are currently classified as Dao/Alpha and Hsx/Alpha. The series of three active regions near centre south of the disc remain the most noteworthy of all the sunspot regions. AR2907 continues to shows growth in its leader spot and its intermediate spots. This is now classified as Dai/Beta-Gamma. AR2908 also continues to show growth in its intermediate spots, and is now classified a Cai/Beta.The final region of the three AR2909 decayed further and mostly inactive. This region produced a C-class flare at 21/1923 UTC in which a coronal dimming and a EUV wave was observed in SDO imagery. Awaiting coronagraph imagery to confirm a CME took place and to analyse for the potential of a Earth-directed CME.

A lengthy filament eruption took place at 21/1728 UTC in the southeast quadrant near AR2912 and AR2914. A weak CME was observed in coronagraph imagery, although given its position is unlikely to be Earth-directed - awaiting further analysis. Recent M class flares originated from AR2016 which is just rotating round the eastern limb. As such, the probability of further M-class flares is now at 40%. All other regions are smaller, simpler, and have shown little change over the past 6 hours.

Solar Wind / Geomagnetic Activity: Solar winds, as measured by the DSCOVR satellite at L1, have been elevated to strong throughout, ranging between 575km/s and a peak of 664km/s at 21/1134 UTC. This is as a result of a high speed stream from CH35 and CH36. Density has generally been average or above average, with a peak of 24 ppcc at 21/0025 UTC. The Interplanetary Magnetic Field Strength (IMF), Bt has been weak throughout, with a peak of 6nT. The all important north-south component (Bz) reached -5nT at 21/0049 UTC. The phi angle was predominately negative throughout (towards the Sun). Geomagnetic activity has been Quiet to Active (Kp 1-4).

Energetic Particles / Solar Radiation: The high energy proton flux (greater than 10 MeV) remained at Background levels. The high energy electron flux (greater than 2 MeV) was at mainly Background levels, but peaked at moderate at 963 pfu at 21/2020 UTC. The associated 24-hour integrated fluence remained well below the Active threshold and stable. A fluence of

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2.47e7 was observed at 22/0000 UTC.

Four-Day Space Weather Forecast Summary

Solar Activity: Solar activity is expected to be predominantly Moderate, with further C-class flares and occasional M-class flares likely - mainly from AR2907, AR2908 and AR2909, and also newly AR2912 rotating onto the east limb. There are also a number of filaments visible in H-alpha imagery and whilst currently stable, they will need monitoring for any potential lift off. The aforementioned recent eruptions near AR2909 and AR2912 will be analysed for any potential Earth-directed CMEs.

Solar Wind / Geomagnetic Activity: A coronal mass ejection (CME) which left the sun on the 20th as result of a M-class flare originating from AR2908 is expected to arrive at Earth on day 2 (23 Dec). Solar winds are expected to remain elevated on day 1 (22 Dec) due to a fast wind from connection with CH36 and CH35, before gradually easing from day 2 (23 Dec). Geomagnetic activity is expected to be Quiet to Unsettled on day 1 (22 Dec) and Quiet to Active on days 2 and 3 (23-24 Dec), with a slight chance of a G1/Minor Storm on the 23rd due to a glancing blow from a CME. Quiet to Unsettled conditions likely on day 4 (25 Dec).

Energetic Particles / Solar Radiation: The high energy (greater than 10 MeV) proton flux is expected to remain at Background levels and below the S1 level, although there is the potential for some increased flux from any flare activity. The high energy electron flux is forecast to be at background at first, but rising day 1 (22 Dec) due to recent solar wind enhancements from the arrival of the fast wind of CH36 and CH35. Peak flux is likely to reach High levels (1000 pfu). Persistently high flux is possible by days 2 and 3 (23-24 Dec), although this may be limited due to the CME arrival on the 23rd. The associated 24 hour fluence is expected to remain below the Active (1e8 integrated pfu) threshold, but there is the chance of fluence rising above on days 2 and 3 (23-24 Dec), albeit with low confidence.

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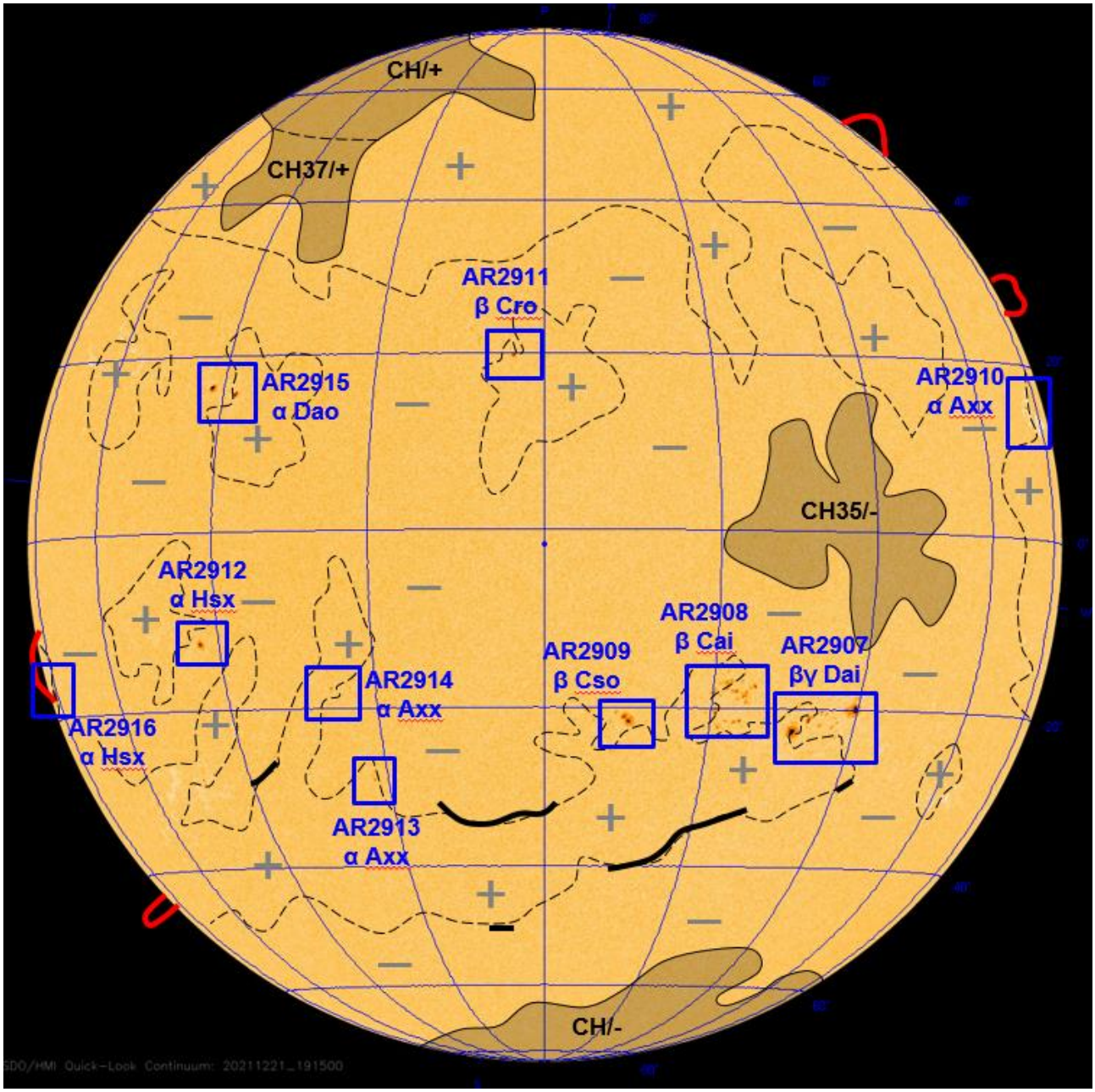
Figure 1. Solar Analysis Valid 20/1915 UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms:

Earth is connected to the fast wind of CH36 and CH35, with solar winds currently elevated at around 570 km/s. Solar winds are likely to remain elevated through day 1 (22 Dec). A gradual decline is then expected on day 2 (23 Dec) as coronal hole effects wane. This is supported by enlil and 27-day persistence which shows a fast wind enhancement until day 1 (22 Dec), and then easing. However, analysis of a CME that left the sun on the 20th indicates an arrival time at Earth on day 2 (23 Dec), which may elevate wind speeds to around 500km/s once again.
Geomagnetic activity is forecast to be Quiet to Unsettled on day 1 (22 Dec), with Active intervals possible. On days 2 and 3 (23-24 Dec), geomagnetic activity is likely to become mostly Quiet, however, the arrival of a weak CME gives rise to the chance of active intervals, and a Chance of a G1 / Minor Storm on Day 3 (23 Dec). Quiet to Unsettled conditions are likely on day 4 (25 Dec).

Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	No	10	30	30	10
Strong	G3	No	1	1	1	1
Severe	G4	No	1	1	1	1
Extreme	G5	No	1	1	1	1

Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
21/0142 UTC	Partial Halo	AR2908	Centre disc	625 km/s	23/0700UTC	Limited shock expected

Figure 2: MOSWOC ENLIL shows the arrival of a CME on the 23rd December.

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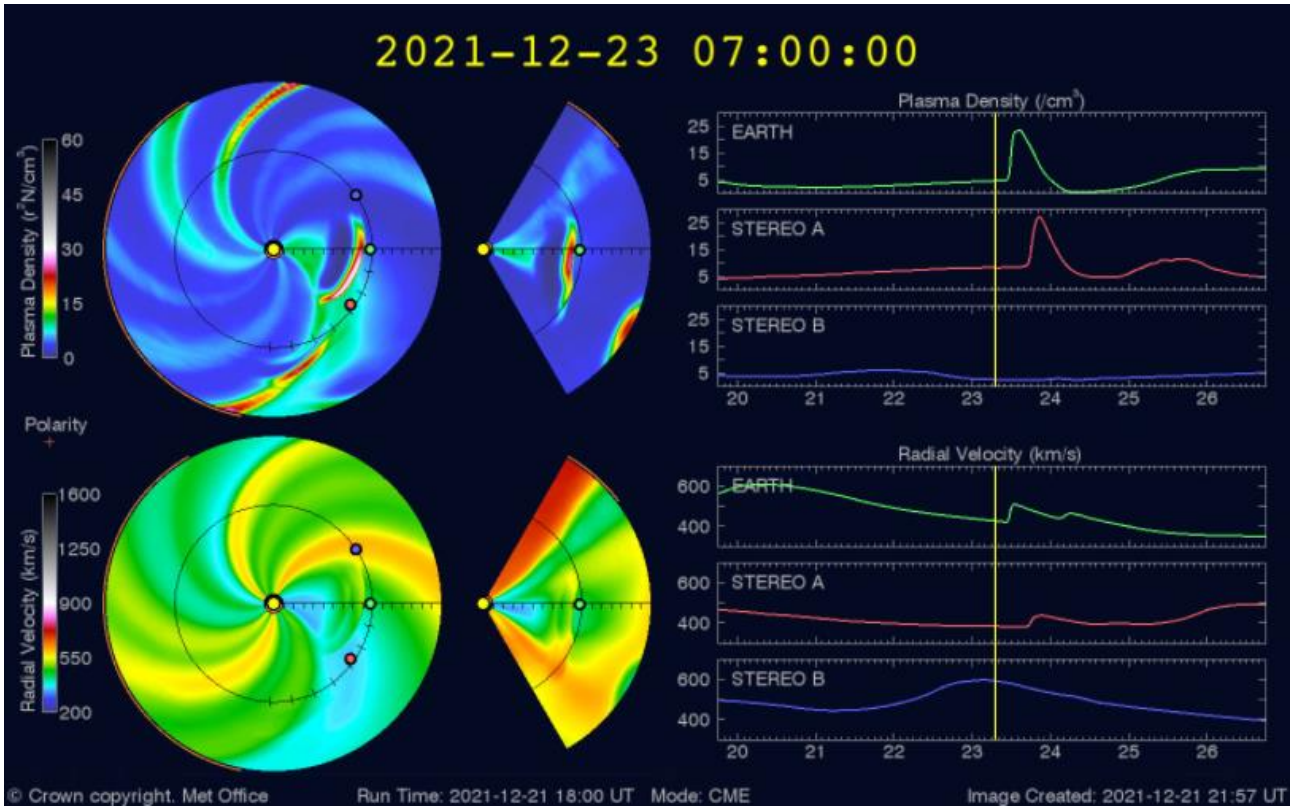

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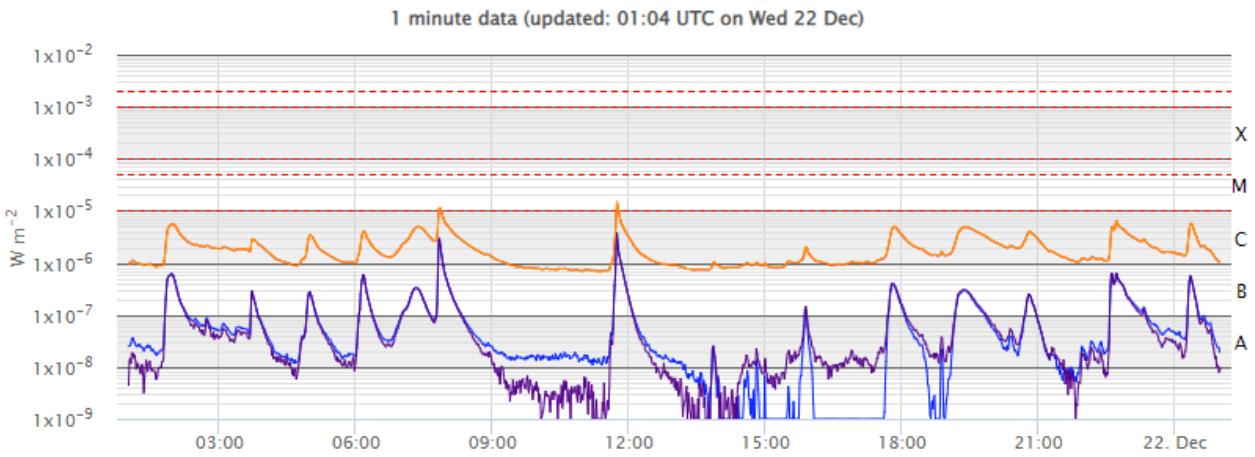
Radio Blackouts - X-Ray Flares:
There are currently ten numbered sunspot regions on the visible disc, which includes two newly numbered regions AR2915 and AR2916 both located in the southeast quadrant. These are currently classified as Dao/Alpha and Hsx/Alpha. The most dynamic and noteworthy sunspots remain near the centre south of the disc, these are AR2907, AR2908 and AR2909.

AR2907 has continued to show growth in its leader spot and its intermediate spots. This is currently classified as a Dai/Beta-Gamma and continues to produce the odd C-class flare. AR2908 also continues to show growth in its intermediate spots and is now classified as a Cai/Beta. AR2909 has recently become more active, producing another C-class flare, which resulted in an eruption of plasma near the region at 21/1905 UTC, which was observed as coronal dimming and a EUV wave in imagery. This has the potential to produce an Earth-directed CME, given it geoeffective location - pending analysis. Recent M class flares originated from AR2016 which has just rotated round the east limb. As such, the probability of further M-class flares is now at 40%. All other regions are smaller, simpler, and have shown little change over the past 6 hours. Solar activity is expected to be predominantly Moderate, with further C-class flares and occasional M-class flares likely - mainly from AR2907, AR2908 and AR2909, and also the AR2916, which is rotating around the east limb.

X Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 M Class	Yes	40	40	40	40
Very Active	R3 to R5 X Class	No	2	2	2	2

Figure 3: GOES X-Ray flares.



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Solar Radiation Storms - (High Energy Protons):

The high energy proton flux (greater than 10 MeV) as observed by GOES-16 is currently at Background levels.

Despite the large number of sunspots on the disc, a number of which are now moving into an improved geoeffective location for radiation storms, their small size and generally simple magnetic structure means that proton rich flaring is unlikely. Background levels are expected to persist, with a chance of some small increases from any notable flares that do occur. However, there is only a very slightly above background risk of rising to the S1 alert level.

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	No	5	5	5	5
Very Active	**≥ S3 ***	No	1	1	1	1

* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)

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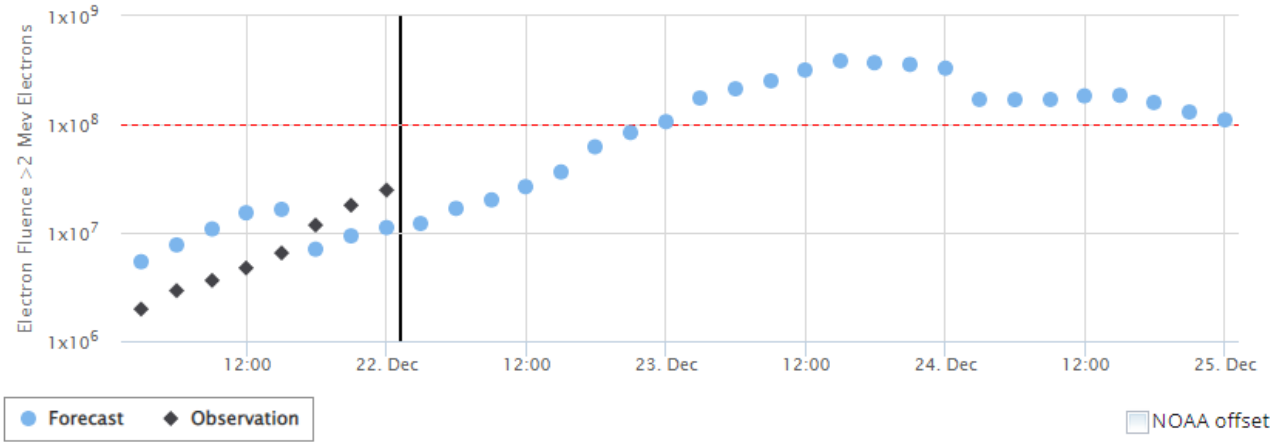
High Energy Electrons Event (≥ 2MeV):

The high energy (greater than 2 MeV) electron flux as observed by GOES-16 is currently at Moderate levels, with a chance of reaching High levels (above 1000 pfu). Moderate to High levels are expected to persist on day 1 (22 Dec), possibly returning to near background levels on day 2 (23 Dec) due to the arrival of glancing blow from a CME, albeit with low confidence. Moderate levels may resume by days 3 and 4 (24-25 Dec) after waning effects from CH36 and CH35.

The associated 24 hour fluence is expected to remain below the Active (1e8 integrated pfu) threshold until day 2 (23 Dec) with a chance of rising above. Whilst this risk increases through the period, it remains low confidence due to uncertainty around the arrival time of a glancing blow from a CME, due to arrive on day 2 (23 Dec). REFM is giving good guidance showing a rising trend for the current solar wind enhancement.

GEO Electron Environment	Level ($cm^{-2}\ sr^{-1}\ day^{-1}$)	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability (Exceedance)			(%)	(%)	(%)	(%)
Active	**≥ 2 MeV ≥ $1x10^8$**	No	30	30	40	40
Very Active	**≥ 2 MeV ≥ $1x10^9$**	No	1	1	1	1

Figure 4: Observed electron fluence from GOES-16 and REFM forecast data – shows a gradual rise to high levels by day 2 (23 Dec) – low confidence due to arrival of a CME on the same day.



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